

Comparative Analysis of Responses to the Two Pertussis Epidemics that Occurred in the Health Districts of Lelouma, Mali and Lola, Guinea from November 2022 to April 2023

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Abstract: *Introduction:* Guinea experienced two pertussis epidemics in two health Regions of the country between 2022 and 2023. The first occurred in two health districts in the Labe region and the second in the Lola health district in Nzerekore. The aim of the study was to compare the two responses and determine the epidemiological, clinical, and evolutionary characteristics of pertussis cases in concerned children, and to identify the risk factors for the commencement of the disease. We conducted a descriptive and comparative cross-sectional study of the response to the two pertussis epidemics from 03 to 16 January 2023 in the prefectures of Lelouma and Mali and from 15 to 25 April 2023 in the prefecture of Lola. Our study population was children suspected of having pertussis living in these localities. *Results:* A total of 146 suspected cases of pertussis were recorded out of 5,831 inhabitants of the affected localities (the overall attack rate was 34 cases per 1,000 inhabitants), with one case of death. During the first epidemic, we recorded 83 cases of Pertussis cough in Linsan Saran and 13 cases in Dougountouny. The median age was 4 years and 54% were boys. The epidemic began on 21 November 2022 in Linsan Saran and cases then appeared intermittently until 20 January 2023. The second epidemic recorded 50 cases, of which 5 were confirmed and one death was reported in the village of Gbee. The epidemic began on 18 March 2023 and ended on 25 April 2023. The lessons learnt from the first epidemic enabled the health authorities to bring the second epidemic under control quickly, and to prevent any further outbreaks and prevent it from spreading to other localities in the health district. In terms of financial resources deployed to contain the two epidemics, out of a total of GNF 261,256,448, 62.78% was used for the second epidemic, compared with 37.22% for the first. *Conclusion:* Our study shows that during both epidemics, the disease affected

children with a median age of 4 and 3 years respectively. The risk factors for the occurrence of pertussis were low vaccination coverage among children with the disease, a history of contact with cases and promiscuity. The two epidemics were studied using the surveillance system set up by the Ministry of Health and implemented by the health district management teams.

Keywords: Comparative Analysis, Pertussis, Epidemics, Health District, Penta 3, Guinea

1. Introduction

Pertussis is an infectious and highly contagious respiratory disease, particularly in children and adolescents, caused by the gram-negative bacterium *Bordetella pertussis* [1]. It causes frequent and prolonged coughing fits. In infants and very young children, it is serious, even fatal [2]. Pertussis is transmitted mainly by large droplets or direct contact with respiratory secretions [3]. There are an estimated 50 million cases of pertussis worldwide each year, with the highest incidence and mortality rate in infants under 4 months of age [4].

In 2014, the WHO still reported 24 million cases of pertussis worldwide in children under the age of 5, including 160,700 deaths. Most cases occur in developing countries, and there are around 16 million cases of whooping cough a year worldwide [5].

To improve the control of pertussis, several countries have included additional booster doses beyond pre-school age in their vaccination programs. Vaccination schedules and the number and type of pertussis vaccines used vary from country to country [6].

In England, a national outbreak of pertussis was declared in 2012 and led to the introduction of the maternal vaccination programme. However, the number of confirmed cases of pertussis continues to exceed the levels observed prior to this epidemic peak [7]. Pertussis epidemics have occurred in secondary schools (11–16-year-olds), probably reflecting declining immunity [8].

In France, since January 2018, vaccination against pertussis, which had previously been recommended, has become and is now one of the 11 compulsory vaccines in early childhood [2].

Despite the proposal for booster vaccinations before school entry and during adolescence, epidemics continue to be observed in primary schools in some countries, including China, Germany, and the United States [9].

In 2019 in the United States, 18,617 cases of pertussis and 7 deaths were observed, with Centers for Disease Control and Prevention (CDC) surveillance reporting an incidence of 5.7/100,000 [10, 11].

In South Africa, between January and 15 September 2022, 147 cases of pertussis were reported, with a steady increase in the number of cases reported during the months of May and July to September. These figures are higher than in previous years, with 169 cases in 2020 and 27 cases in 2021 [12].

In Mali, in 2020, OM. Kampo et al reported 23 cases and 0 deaths during an investigation into a whooping cough epidemic in Sikasso [13].

In Guinea, the latest national surveys revealed that only 23% of children had received all their doses of vaccine. Compliance with children's vaccination schedules remains a health priority [14]. It should be noted, however, that this is the first time Guinea has recorded an epidemic linked to this disease. It should be noted, however, that this is the first time that Guinea has recorded an epidemic linked to this disease.

On 31 December 2022, the Lelouma prefectural health department was alerted by staff at the Linsan Saran improved health center and district officials to the presence of cases of dry cough with coughing fits among children in the village of Diawoya, Kokolou district, sub-prefecture of Linsan Saran. A preliminary investigation was carried out from 31 December 2022 to 01 January 2023 and resulted in the registration of 16 suspected cases of whooping cough. Following this notification, the Public Health Emergency Operations Centre (COU-SP) of the Lelouma health district was activated in alert mode. A crisis meeting was organized on 02 January 2023 by the Prefectural Epidemic Alert and Response Team (EPARE).

On 16 January 2023, Mali's Prefectural Health Department was informed by its counterpart in Lelouma that two (2) children from a cohort of pertussis cases under surveillance in the village of Ley Sere (Linsan sub-prefecture) had been diagnosed with the disease had been moved to Ley Fello Wellya in the Kokouma district (Dougountouny sub-prefecture). All cases were sampled and sent to the reference laboratory in Conakry.

Following these alerts, investigation teams were set up as a matter of urgency and went to the site the same day to carry out preliminary and then in-depth investigations.

On 18 March 2023, the head of the health center in the NZoo sub-prefecture received an alert from a community intermediary concerning the presence of cases of dry, hacking cough among children in the village of Gbee in the same sub-prefecture (Lola health district).

Following this alert, an emergency meeting was held at the prefectural health directorate (DPS) and an investigation team was set up, made up of health district officials (the doctor in charge of the MCM, a laboratory technician, the communications officer, the head doctor of the epidemiological treatment center (CTEPI) and the head of the Nzoo center). An official from the Agency national de sécurité sanitaire (ANSS) has been mandated to investigate suspected cases reported by healthcare workers to confirm the existence of the epidemic.

These figures show that, in the context of these localities,

cases of vaccine-preventable diseases are possible.

In view of all this data, several questions arise: are the vaccination coverage figures for these localities communicated by the health authorities reliable? are the children vaccinated? are the cases of whooping cough reported among vaccinated children (0-23 months)? are the response activities being carried out on time? is there a difference in costs in the two epidemics?

In order to answer all these questions, we decided to carry out a comparative analysis of the response to pertussis in the localities affected by the two epidemics. To do this, we compared the response to the two (2) epidemics while determining the epidemiological, clinical and evolutionary characteristics of the cases of pertussis in the children affected through the distribution of cases in the localities affected, the immunization coverage of children targeted by the EPI, assessing the immunization coverage in routine Penta 3, describing the clinical symptoms of the patients, highlighting the cost of each epidemic and the use of the funds mobilized, and identifying the risk factors for the occurrence of the disease.

2. Materials and Methods

2.1. Parameters

Labe and Nzerekore regions, the localities affected by the epidemics, are among the 8 health regions of the Guinean health system.

Labe being a neighboring region of the Republic of Mali and Senegal. In 2022, its population was estimated at 125,2857, with a density of 54 inhabitants/km². It has 5 health districts (Labe, Koubia, Lelouma, Mali and Tougue),

Nzerekore being a neighboring region of Côte d'Ivoire and Liberia. It is the region where all the epidemics (Ebola, Marburg, Lassa fever) reported in Guinea over the last ten years have occurred. It comprises six prefectures: Nzerekore, Macenta, Gueckedou, Lola, Yomou and Beyla. Its population was estimated at 1,664,000 (RGPH 2014) with a density of 44 inhabitants per Km².

The sub-prefectures of Linsan Saran in the Lelouma health district, Dougountouny in Mali and Nzoo in the Lola health district served as the areas for the survey.

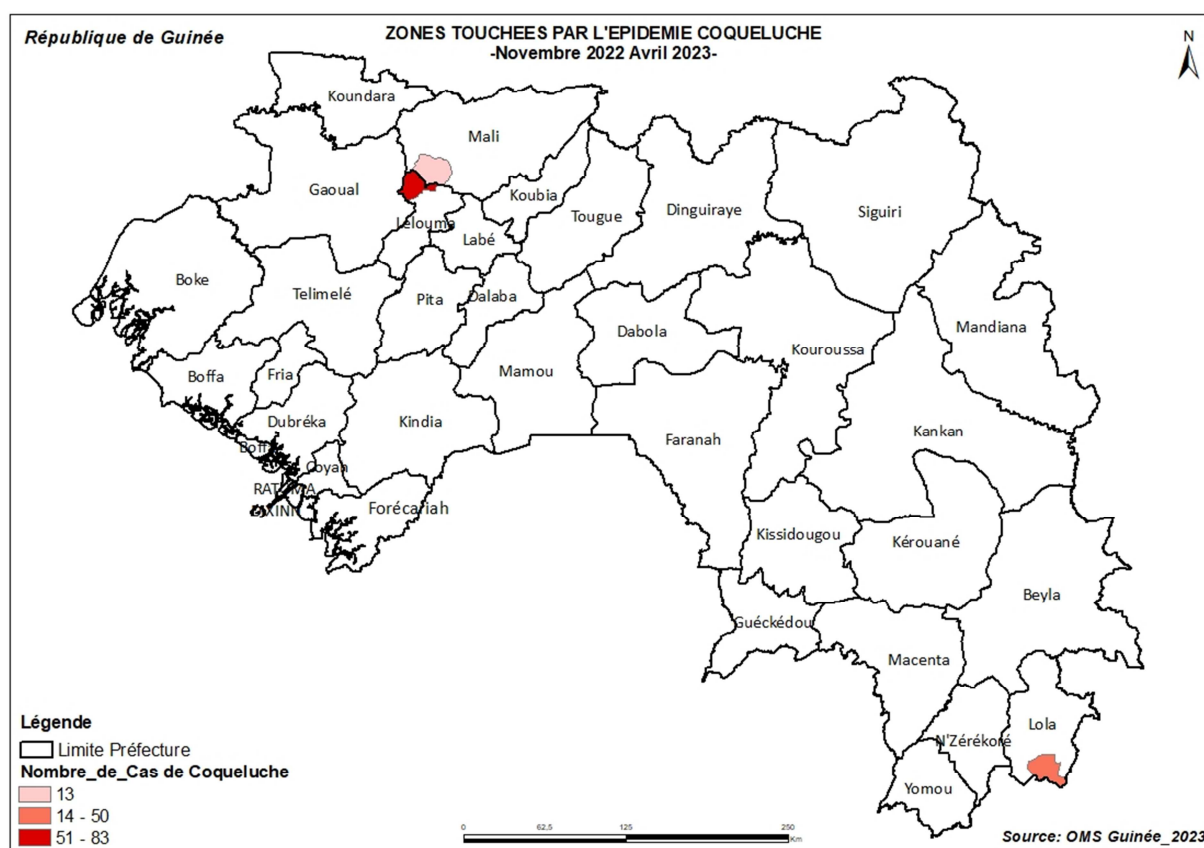


Figure 1. Sub-prefectures affected by pertussis epidemics from 21 November 2022 to 25 April 2023.

2.2. Type and Duration of Study

We conducted a descriptive cross-sectional study comparing the responses to the two pertussis epidemics that occurred from 03 to 16 January 2023 in the prefectures of Lelouma and Mali and from 15 to 25 April 2023 in the

prefecture of Lola.

2.3. Populations Surveyed

The survey covered the population living in the localities (Misside, Ley Fello Wellia, Hassanamba, Hore Bomby, Foulasso, Madina Horé Bowal, Kokouma Centre, Diawoya,

Kokolou, Ley Sere, Ley Fetto, Sinthourou, Tomadougou, Gbee, Doromou, Bourata, Deguelehoumo) of the sub-prefectures of Linsan saran, Dougountouny and Nzoo. Our study populations were children suspected of having pertussis living in these localities (see Table 1).

Table 1. Distribution of study population by prefecture, sub-prefecture and locality affected from 03 January to 25 April 2023.

District sanitaire	Sous-prefecture	Villages touchés
Mali	Dougountouny	Misside
		Ley Fello Wellia
		Hassananba
		Hore Bomby
		Foulasso
		Madina Horé Bowal
		Kokouma Centre
		Diawoya
		Kokolou
		Ley Sere
Lelouma	Linsan Saran	Ley Fetto
		Sinthourou
		Tomadougou
		Gbee
		Doromou
Lola	Nzoo	Bourata
		Deguelehoumo

2.4. Operational Definitions of Concepts

Suspected case: A suspected case of pertussis was defined as any person of any age suffering from a persistent cough (> 1 week) with at least one of the following symptoms: emetogenic cough with a nocturnal peak, coughing fits sometimes followed by the emission of a high-pitched sound (rooster crow), mucous sputum, post-cough vomiting or no other apparent cause.

During the first epidemic, no biological confirmation was carried out in Guinea due to a lack of reagents. Given this situation, all samples were sent to France.

- 1) Vaccinated pertussis suspects: All pertussis suspects who have received the three doses of pertussis vaccine and within the required timeframe (6th, 10th, and 14th week).
- 2) Suspected cases of unvaccinated pertussis: Any suspected case of pertussis who has not received any dose of pertussis vaccine.
- 3) Suspected case of incompletely vaccinated pertussis: Any suspected case of pertussis who has received one or two doses of pertussis vaccine and has not completed vaccination as indicated.
- 4) Laboratory-confirmed case: Any laboratory-confirmed (PCR positive) suspected case of pertussis.
- 5) Epidemiologically linked case: any suspected case of pertussis that has not been laboratory confirmed but is linked to a laboratory-confirmed case or an epidemiologically linked case of pertussis.
- 6) Clinically compatible case is any suspected case of emetogenic cough with a nocturnal peak, coughing fits sometimes followed by the emission of a high-pitched sound (rooster crow), mucous sputum, post-cough

vomiting, with no or insufficient specimen collection and which has not been epidemiologically linked to a case of pertussis living in the affected localities during the epidemic periods.

2.5. Data Collection

Data were collected from investigation forms for suspected cases of pertussis, contact registration forms and the rapid monitoring of vaccination coverage form. The files were analysed in the health facilities concerned. The data collection consisted of looking for suspected cases according to the operational definition in the consultation registers and interviewing health workers and community relays to identify non-reported cases that might have gone unnoticed in the health facilities. The active search for suspected cases was also carried out in the open air in the communities and consisted of looking for other suspected cases around each suspected case in the villages concerned. Nasopharyngeal swabs were taken from children suspected of having pertussis. Cases sampled were those who had not received antibiotic therapy during the current episode. The nasopharyngeal swabs were sent to the national reference laboratory of the Institut National de Santé Publique (INSP) with support from the WHO.

Penta₃ vaccination coverage was monitored in the communities by checking children's medical records and asking parents about their children's vaccination status. All children for whom proof of vaccination for these three doses appeared in the health record or in the tools used to monitor children's immunization schedules were fully or partially vaccinated. These immunization coverage data were compared with routine EPI data in the three sub-prefectures over a previous 5-year period.

In the Lelouma health district, data on the first 22 notified cases were extracted from the survey report. Additional cases to those already notified were then actively sought in the community by door-to-door research in the various villages and in the consultation registers of the respective health centers. All households in these localities were visited.

The children's parents were interviewed using a structured questionnaire including socio-demographic information (age, sex, village of origin and residence), clinical information (signs, date of onset of signs, treatment received and course) and exposure factor (vaccination status), and the children were examined. Vaccination cards and archived vaccination records were then examined. The data collected enabled us to draw up a linear list of cases.

2.6. Data Entry and Analysis

The data collected was entered into a linear list created in Excel, then cleaned and analyzed. Epi Info 7.2.4 and Excel 2013 were used for the analysis. Medians were calculated for quantitative variables, and frequencies and proportions for qualitative variables.

The age variable was discretized into age groups (< 1 year, 1-4 years, 5-9 years and 10 years and over) prior to analysis.

The results are presented in the form of tables, figures, and maps.

3. Ethical Aspects

The survey was part of the normal framework for the control of notifiable diseases with epidemic potential in Guinea (PNDS 2015-2024). It was authorized by the health authorities. Patient anonymity was respected. Pertussis cases were treated free of charge with appropriate drugs and children who had not been vaccinated or fully vaccinated received the service package.

4. Results

From 21 November 2022 to 25 April 2023, 146 suspected cases of pertussis were notified in the sub-prefectures of: Linsan Saran (Lelouma prefecture) with 83 cases, Dougountouny (Mali prefecture) 13 cases and Nzoo (Lola prefecture) 50 cases. Of these cases, 26 were reported to health facilities (17.8%) and 126 cases were detected during investigations (82.19%) out of a population at risk of 5,831 in

the various localities affected by the epidemics). Of these 146 reported suspected cases of pertussis, 15 were confirmed by the laboratory, 10 by the National Reference Centre for Pertussis and Other Bordetella Infections at the Pasteur Institute in Paris, the other 5 by the National Institute of Public Health in Guinea, and the remainder by an epidemiological and clinical link. The last outbreak was reported in the prefecture of Lola with 50 suspected cases in March 2023. Of the 10 samples sent to France, 7 tested positive for pertussis. In the field, the cases were confirmed on the basis of a series of clinical arguments, hence the term "suspected case". Bordetella DNA was detected in 7 of the 10 samples sent to France by IS481 qPCR. For two other samples (INSP_COQ_0003 and INSP_COQ_0006) the presence of B. pertussis by PCR PTa was confirmed; and in sample INSP_COQ_0006 Bordetella holmesii. (PCR h-IS1001 was detected).

Of the 50 samples analyzed by the laboratory of the National Institute of Public Health in Guinea, 5 were positive for pertussis. All cases were treated with Azithromycin and Erythromycin and all unvaccinated or incompletely vaccinated children were vaccinated.

Table 2. Breakdown of suspected pertussis cases by sub-prefecture and affected localities from 21 November 2022 to 25 April 2023.

Origin of cases	Population of localities affected	Number of cases	%
Dougountouny (Mali)			
Misside	302	2	15.38
Ley Fello Wellia	121	2	15.38
Hassananba	202	3	23.08
Horé Bomby	221	1	7.69
Foulasso	201	1	7.69
Madina Horé Bowal	112	1	7.69
Kokouma Centre	257	3	23.08
Total	1416	13	100
Linsan Saran (Lelouma)			
Diawoya	213	26	31.33
Kokolou	687	3	3.61
Ley Sèrè	76	35	42.17
Ley Fetto	425	6	7.23
Sinhourou	51	10	12.05
Tomadougou	36	3	3.61
Total	1488	83	100
Nzoo (Lola)			
Gbée	540	34	68.
Bourata	607	3	6.0
Deguelehoumo	180	13	26.
Total	1327	50	100
Total general	4231	146	3.45

Table 3. Breakdown of suspected pertussis cases by sub-prefecture according to vaccination status from 21 September 2022 to 25 April 2023.

Sous-prefecture	Suspected cases	Vaccines	%	Non immunized	%
Linsan Saran	83	0	0	83	100
Diugountounny	13	0	0	13	100
NZoo	50	6	12.00	44	88.00
Total	146	6	4.11	140	95.89

The highest number of cases was reported in the villages of Ley Seré 35 (sub-prefecture of Dougountounny) and Gbée 34 (sub-prefecture of Nzoo).

Almost all the cases (140), or 95.89% of the children, had not been vaccinated against whooping cough. Only 6 other

cases had received at least one dose of vaccine, i.e. 4.11% (incompletely vaccinated).

Table 4. Distribution of pertussis cases by sub-prefecture according to sex from 21 November 2022 to 24 April 2023.

Sous-prefecture	Sexe	Population	Nbre de cas	%
Dougountounny (Mali)	Masculin	590	6	46
	Feminin	826	7	54
	Total	1416	13	100
Linsan Saran (Lelouma)	Male	670	46	55.4
	Female	818	37	44.6
	Total	1488	83	100
Nzoo (Lola)	Male	551	31	40.5
	Female	749	19	59.5
	Total	1327	50	100
TOTAL		4231	146	3,45

Table 5. Distribution of pertussis cases by sub-prefecture and age group from 21 November 2022 to 25 April 2023.

Tranche d'age	Dougountounny	Linsan Saran	Nzoo	Total	%
< 1 an	2	3	4	9	6.16
1- 4 ans	10	31	21	62	42.47
5-9 ans	0	27	18	45	30.82
10 ans et plus	1	22	7	30	20.55
TOTAL	13	83	50	146	100

Boys accounted for 83 suspected cases of pertussis, or 56.8%.

Description of the 1st case of the first epidemic:

A 5-year-old girl suffering from a cough since 21 November 2022 in the village of Diawoya, whose parents claim never to have travelled in the 21 days before the onset of the disease. The girl is said to have infected 4 of her brothers living in the same house, aged between 5 and 12. They began to show the same signs on 30 November 2022. Since then, other cases of coughing have appeared in the village and neighboring villages.

The 1st case was notified on 21 November 2022, and it was only on 28 November that we observed a reappearance of cases until 30 November, when 4 cases were observed. Then intermittently until 20 January 2023 and a peak on 17 December with 5 cases. The intermittent outbreak continued until 12 January 2023, when the last cases were recorded.

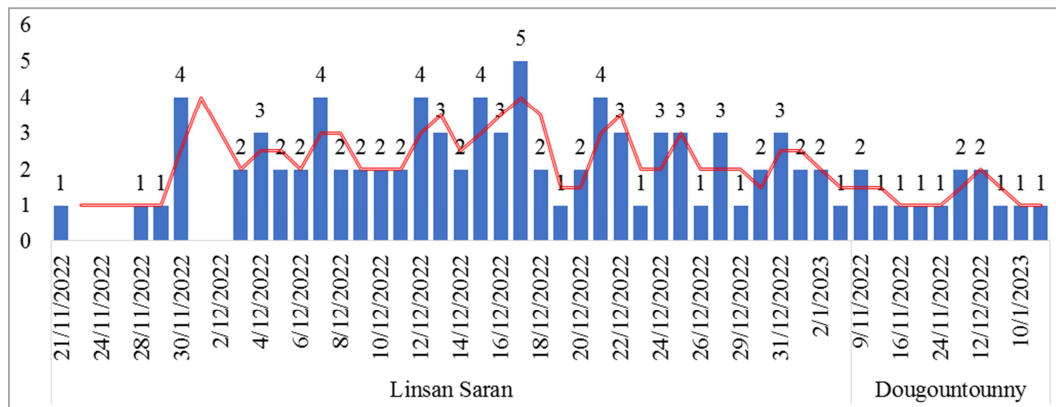


Figure 2. Change in the number of pertussis cases in the sub-prefectures of Linsan Saran (Lelouma prefecture) and Dougountounny (Mali prefecture) from 21 November 2022 to 25 April 2023.

The graph below shows the Penta 3 vaccination situation in the Linsan Saran (Lelouma prefecture) and Dougountounny (Mali prefecture) health centres in 2019-2022.

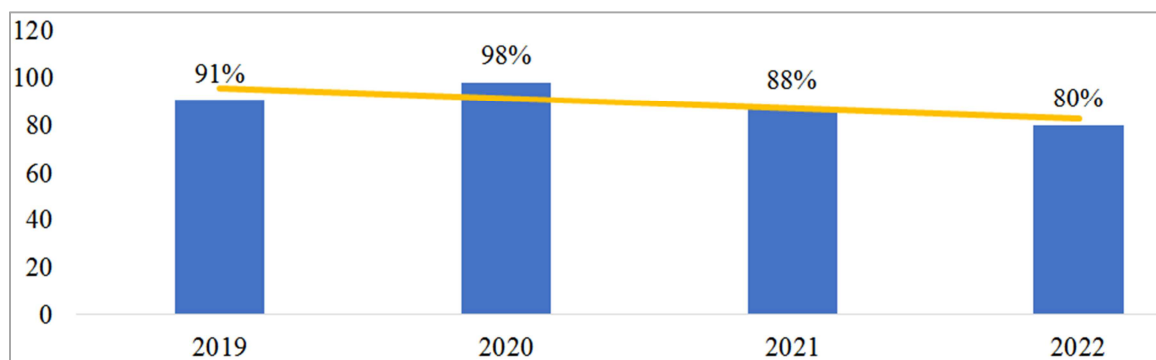


Figure 3. Assessment of routine Penta3 vaccine coverage from 2019 to 2022 in the Linsan Saran (Lelouma prefecture) and Dougountounny (Mali prefecture) health centers.

This graph shows that in 2019 and 2020, the Linsan Saran and Dougountounny health centres achieved Penta 3 vaccination coverage above the national threshold of 90% set

by the EPI. However, for the period 2021 and 2022, these rates were below the targets.

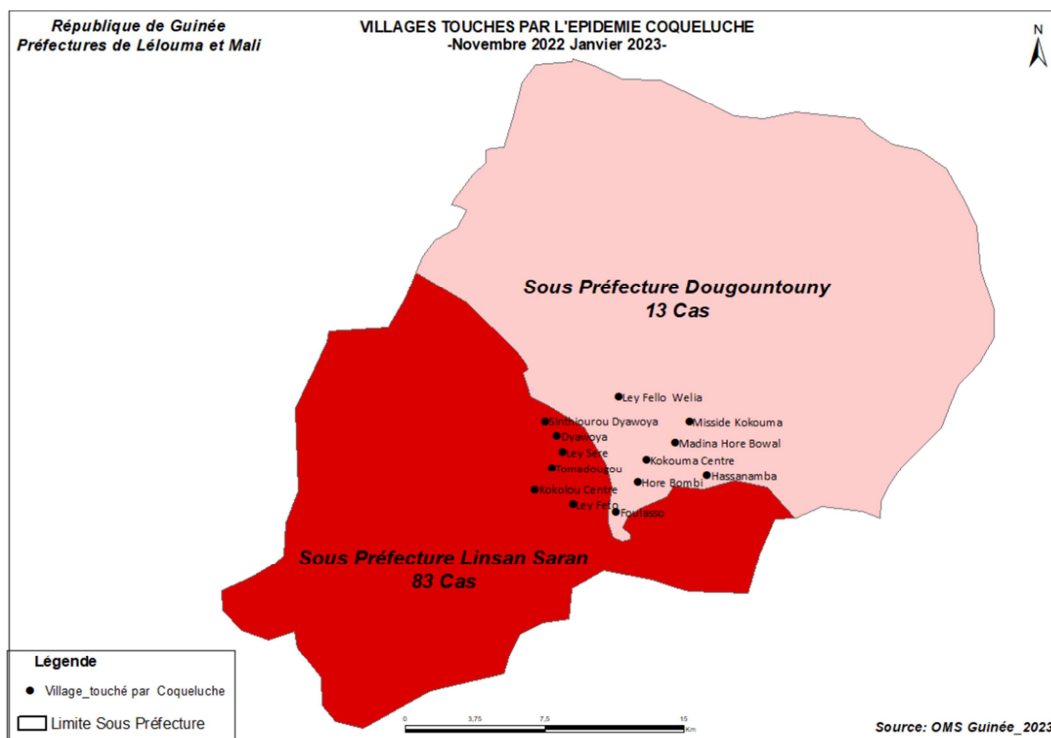


Figure 4. Spatial distribution of pertussis cases in the sub-prefectures of Linsan Saran and Dougountouny from 21 September to 16 January 2023.

Description of the first case of the Nzoo outbreak in the prefecture of Lola

The case involved an 8-year-old girl living in the village of Gbée who had travelled from the prefecture of Kankan centre in January 2023 to spend her holidays there. On her return, according to information gathered from the Relais Communautaires (RECO) and the local teacher, the girl

started coughing one to two weeks after her return from Kankan. Gbée is a locality with a single classroom where all the pupils drank from the same cup. The outbreak is thought to have spread from there. A few days after the first case, the teacher began to observe other cases of coughing in the classroom. The potential source of this outbreak would be intermittent, with human-to-human transmission.

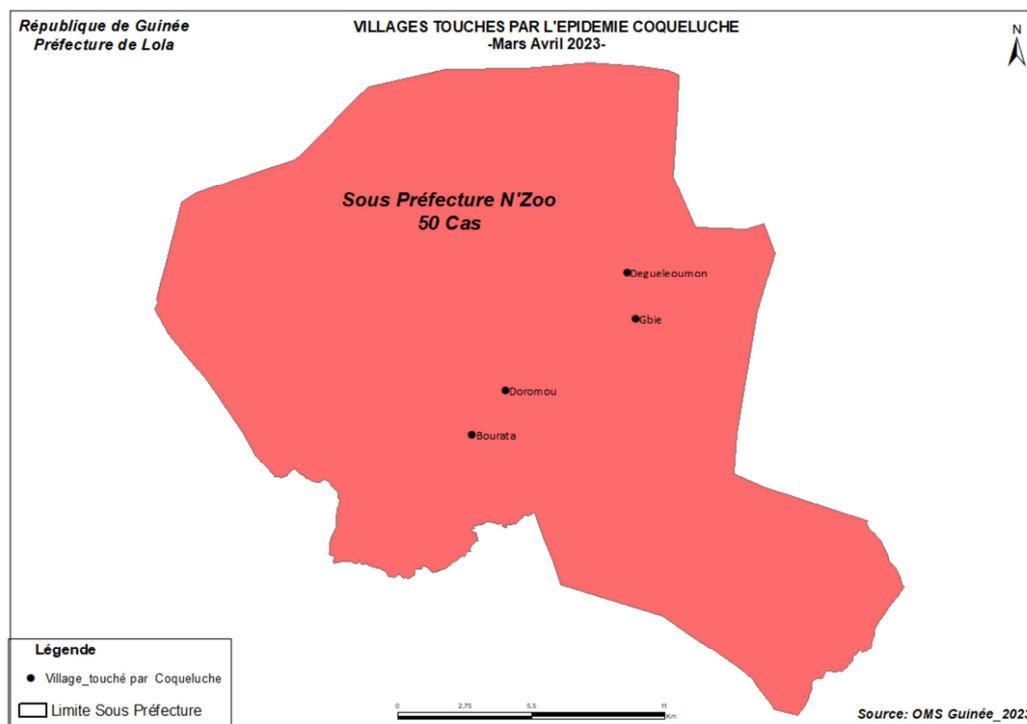


Figure 5. Trend in the number of pertussis cases in the sub-prefecture of Nzoo, Lola prefecture, from 05 February to 25 April 2023.

The case that occurred on 05 February 2023 is the index case of this outbreak. Two peaks were observed, on 18 March and 14 April 2023, with 8 and 6 cases respectively.

The graph below shows the Penta 3 vaccination situation at the Nzoo health center between 2018 and 2022.

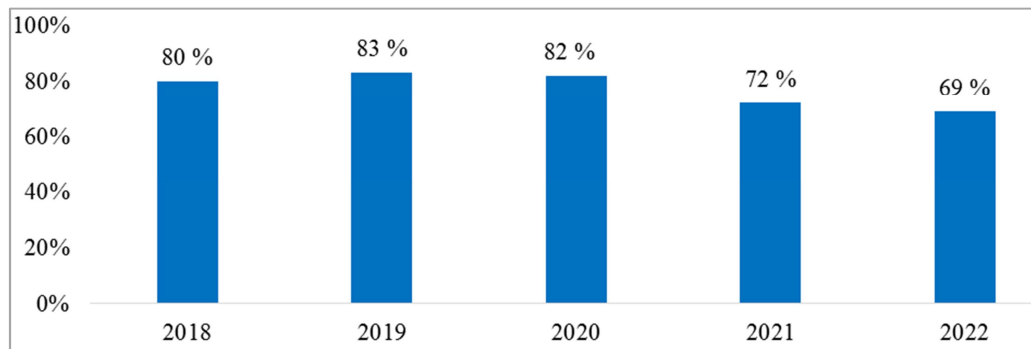


Figure 6. Assessment of routine Penta 3 vaccination coverage in the Nzoo health centre (Lola prefecture) from 2018 to 2022.

Analysis of this graph shows that from 2018 to 2022, the Nzoo health center did not achieve the national Penta 3 vaccination coverage target of 90%. From 2019 onwards, we observed a drop in coverage until 2022. This situation could be one of the risk factors for the outbreak of pertussis in the area.

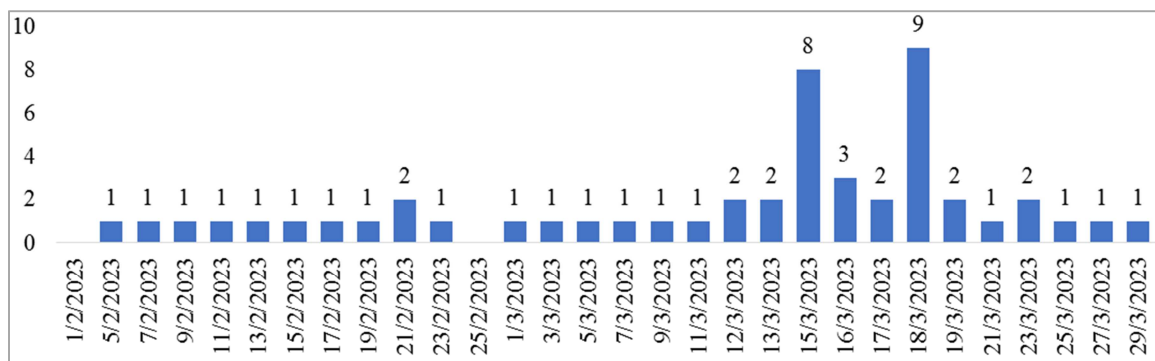


Figure 7. Trend in the number of pertussis cases in the sub-prefecture of Nzoo, Lola prefecture, from 05 February to 25 April 2023.

The risk factors identified are essentially linked to the routine vaccination coverage of the populations covered by the health centers.

Table 6. Risk factors for the occurrence of pertussis cases in the sub-prefectures of Linsan Saran, Dougountouny and Nzoo.

Risk factors	Linsan Saran	Dougountouny	Nzoo	Effectif	%
Non immunized	83	13	44	140	96.30
Antecedents de contact	80	12	42	134	92.29
Promiscuité	60	10	35	105	70.24

The table shows that almost all patients were unvaccinated (96.30%), had a history of contact with cases (92.29%) and lived in crowded conditions (70.24%). These could be risk factors for the occurrence of pertussis in these different localities.

Table 7. Distribution of signs and symptoms presented by patients, by sub-prefecture.

Signes et symptômes	Linsan Saran	Dougountouny	Nzoo	Effectif	%
Coughing cough	83	12	51	146	100%
Fever	60	8	45	113	77%
Vomiting	71	12	43	126	86%
Headaches	30	0	42	72	49%
Dyspnoea	0	0	8	8	5%
Anorexia	30	12	27	69	47%
Haemoptysis	20	0	0	20	14%

In terms of signs and symptoms, we found that 100% of children had a coughing fit, followed by vomiting and fever in 86% and 77% of sick children respectively. Dyspnoea was the least common symptom, reported by only 5% of children.

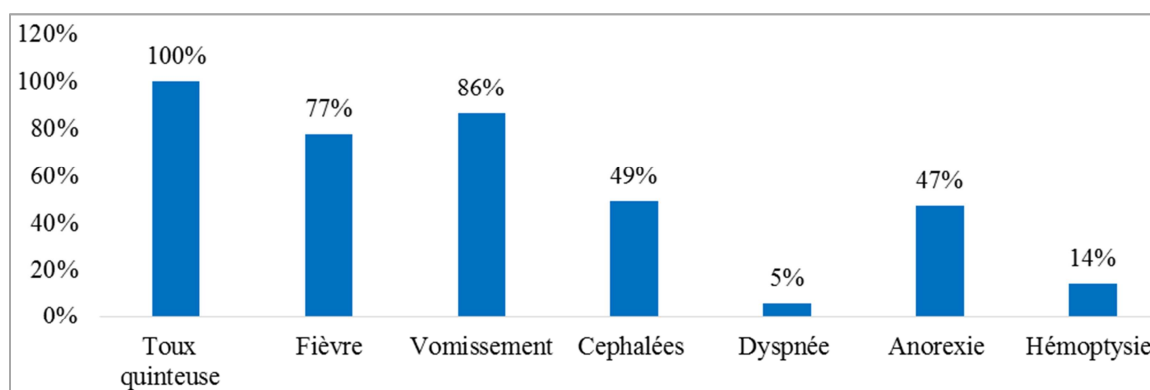


Figure 8. Breakdown of signs and symptoms presented by patients, by sub-prefecture.

The table below provides several comparisons between the measures taken to contain the two epidemics.

Table 8. Comparison of activities carried out during the response to the two pertussis epidemics in the three sub-prefectures November 2022-March 2023.

Activities carried out	Completion date of the actions	
	Linsan Saran and Dougountounny	NZoo
Alerte	December 31th 2022	18/3/2023
Preliminary Investigation	January first, 2023	19/3/2023
In-depth investigation	January 3 to 6, 2023	27/3/2023
Samples collection	January 3 to 6, 2023	27/3/2023
Transport of samples	January 26th 2023	27/3/2023
Confirmation of diseases	February 2nd, 2023	29/3/2023

In order to analyse the management of the funds made available to deal with the two epidemics, we compared the use of funds according to the activities undertaken.

Table 9. Comparison of funds used against the two whooping cough epidemics according to the activities undertaken during the response in the districts of Lelouma, Mali and Lola.

Activities undertaken during the response	Health district			Total en GNF
	Lelouma	Mali	Lola	
	Linsan Saran	Dougountounny	Nzoo	
Investigator bonuses	6,750,000	10,000,000	4,000,000	20,750,000
Active research in the field	7,200,000	8,000,000	3,500,000	18,700,000
Vaccination in the field	3,000,000	5,000,000	5,250,000	13,250,000
Supervision visit by the DPS and IRS	7,200,000	2,680,000	35,120,000	45,000,000
Cost of medicines	4,000,000	2,250,000	7,081,000	13,331,000
Coordination meetings	2,250,000	450,000	8,520,000	11,220,000
WHO field missions from Conakry	0	0	36,926,923	36,926,923
WHO mission to the sub-offices (Labe and Nzerekore)	540,000	513,000	45,644,000	46,697,000
Telephone call credits Internet connection	1,200,000	360,000	3,995,000	5,555,000
Daily tracking of contacts	6,300,000	11,340,000	6,300,000	23,940,000
Investigating alerts	900,000	4,400,000	4,800,000	10,100,000
Transporting samples	2,892,000	0	2,643,150	5,535,150
Routing of inputs	5,013,750	5,013,750	223,875	10,251,375
Sous-total	47,245,750	50,006,750	164,003,948	
TOTAL GENERAL	97,252,500		164,003,948	261,256,448

Table 10. Comparison of funds used against the two pertussis epidemics in relation to the response activities carried out by the districts of Lelouma, Mali and Lola.

Response activities carried out by health districts	Health district	
	Lelouma et Mali	Lola
Supervision visit by the DPS and IRS	9,880,000	35,120,000
WHO field missions from Conakry	0	36,926,923
WHO mission to the sub-offices (Labe and Nzerekore)	1,053,000	45,644,000
Cost of DPS, IRS supervision mission from Conakry and sub-office field visit	10,933,000	116,690,923
	11,24%	71,15%
Response activities, including the purchase of medicines, transport of samples, etc.		
Buying drugs	6,250,000	7,081,000
Active research in the field	15,200,000	3,500,000

Response activities carried out by health districts	Health district	
	Lelouma et Mali	Lola
Belt vaccination	8,000,000	5,250,000
Daily tracking of contacts	17,640,000	6,300,000
Investigating alerts	5,300,000	4,800,000
Coordination meeting	2,700,000	8,520,000
Purchasing inputs	28,920,000	2,643,250
Transporting samples	10,027,500	223,875
Call and internet connection credits	1,560,000	3,995,000
Cost of response activities, including purchase of medicines and transport of samples	95,597,500	42,313,125
Percentage	88,76%	28,85%
TOTAL	97,255,000	164,003,948

With regard to the costs used for the response to the two epidemics, the total cost was 261,256,448 GNF, of which 164,003,948 GNF, or 62.78% of the total amount, was used for the response in the sub-prefecture of Nzoo, against 97,255,000 GNF, or 37.62% of the overall total, used for the response to the epidemic that took place in the sub-prefecture of Nzoo, in the prefecture of Lola.

5. Discussion

Pertussis is a rare disease which had even disappeared in Guinea. It remains a public health problem because of its seriousness, especially in isolated areas. Because of the isolation of the localities affected, the attention of the health authorities in the health districts of Lelouma, Mali and Lola must be focused on specific strategies to guarantee the availability of health services to the population, as well as human and financial resources. In order to prevent the recurrence of this type of epidemic, which disappeared decades ago, intensified routine vaccination campaigns need to be organized on a regular basis to prevent any further epidemics in the future.

The two epidemics were investigated thanks to the surveillance system put in place by the Ministry of Health, which was well respected by the district management teams. The combined efforts of these authorities and the support of technical and financial partners, especially the World Health Organization, enabled the two epidemics to be rapidly contained and brought under control. A system that allows district management teams to carry out the biological tests needed to rapidly confirm the epidemic would be useful. These epidemics could have been avoided and/or rapidly contained if children had been vaccinated if the diagnosis had been made early and if appropriate treatment had been instituted as soon as the first cases occurred.

An assessment of routine vaccination coverage in the VAR from 2019 to 2022 was carried out, and vaccination coverage data was compared with routine EPI data from the health center over a previous 5-year period.

However, it should be noted that the management of this epidemic was not easy, which could be explained by the fact that the health workers working in the various health facilities had never experienced this type of epidemic in their respective areas. This was a new disease for them, and its management required an in-depth review of the literature to equip them with the knowledge they needed to manage it

appropriately.

In-depth investigations were carried out, identifying other suspected cases from consultation registers.

In our country, the Emergency Operations Centre (EOC) is a designated place for gathering and disseminating information, and for analyzing the situation. It is here that emergency response decisions are taken and implemented.

Investigations have led us to conclude that there are epidemics of pertussis on a clinical basis, with subsequent biological confirmation. The spread and long duration of the epidemic (from November 2022 to April 2023) can be explained by several factors. Firstly, almost all (96.30%) of the cases were unvaccinated or incompletely vaccinated. Secondly, diagnosis was delayed, and the localities concerned had no health facilities capable of providing an appropriate response. The overall attack rate was 146 per 4,231 inhabitants, or 34 per 1,000 inhabitants.

Overall, the case fatality rate was 0.68% (1 death out of 146 suspected cases). The other 145 suspected cases of pertussis were undergoing antibiotic treatment or had already been declared cured and placed under epidemiological surveillance. Our study differs from that of E. Kalthan et al in Central Africa, who found that 13 patients died out of 213 recorded, giving a case-fatality rate of 6.1% [15].

Male children predominated, with 57% of cases and a sex ratio of 1.3. In the sub-prefecture of Dougountouny, there were fewer boys (6 cases) than girls (7 cases). However, in the sub-prefecture of Nzoo, boys were less affected (40.5%) than girls (59.5%).

In terms of age, the 1 to 4 age group was the most affected (42.47%), followed by the 5 to 9 age group (30.82%). The median age was 5.5 years, with a range of 1 to 17 years, and 62 cases were in the 1 to 4 age group. We noted that the age group least affected was less than one year (6.16%). Our study differs from that reported by Addisu Gize Yeshanew et al in Ethiopia in 2022. These authors investigated 122 cases, more than half (52.5%) of which were girls, and the overall attack rate (AR) of pertussis cases in the group was 8.6/10,000 population [16].

In terms of vaccination status, almost all the cases (140), or 95.89% of the children, had not been vaccinated against pertussis. However, 6 other cases had received at least one dose of vaccine, i.e. 4.11% (incompletely vaccinated). Our results are lower than those found by P. Vic and J. Puech in the pediatrics and neonatology department of the Cornouaille hospital in France, where 50.4% of sick children were fully

vaccinated against pertussis [17]. This rate was homogeneous in each of the 3 groups: 50.5% in group A, 50.3% in group B and 50% in group C.

The high proportion of unvaccinated children in the areas where the epidemics were reported testifies to the weakness of the routine EPI and the advanced strategies for finding children lost to follow-up with zero doses, thus constituting a group susceptible to contracting pertussis over time.

At the Dougountouny and Linsan Saran health centers, administrative data on Penta3 vaccination of children show that for the period 2019 (91%) and 2020 (98%), the objectives were achieved, i.e. vaccination coverage of over 90%. However, this coverage will fall from 88% in 2021 to 80% in 2022. Rapid monitoring of vaccination coverage at Penta3 showed that only 28% of children under 5 years of age encountered in the community during active research had received at least one dose of vaccine, based on the booklet presented or on parental declaration. The remaining 72% of children had not been vaccinated.

For the Nzoo health center, analysis of the administrative data shows that from 2018 to 2022, the Nzoo health center did not achieve the national Penta 3 vaccination coverage target, which is generally set at 90%. Over the last three years, Penta3 vaccination coverage in this sub-prefecture has fluctuated between 80% in 2018, 83% in 2019 and 82% in 2020. However, from 2021 to 2022, coverage will fall from 79% in 2021 to 69% in 2022. This situation shows that there is a large proportion of children who, because they have not been vaccinated, are likely to develop vaccine-preventable diseases, including whooping cough.

A comparison of administrative data and data from rapid monitoring of vaccination coverage showed that of the 34 children under the age of 5 seen in the community, only 26% had received at least one dose of vaccine. The remaining 74% had received no dose of any type of vaccine.

The village of Ley Seré was the worst affected by the epidemic, with 35 cases. This could be linked to the fact that most of the children share the same school and family environment, but also to the community's lack of knowledge about how to prevent whooping cough (schoolchildren sharing the same cup to drink water at school). With regard to Penta 3 administrative vaccination coverage in the Nzoo health center, the analysis shows that over a period of 5 consecutive years (2018 to December 2022), the health center has never reached the vaccination target of 90%. This shows a high proportion of children not vaccinated against whooping cough and vaccine-preventable diseases (*Haemophilus influenzae meningitis*, diphtheria, tetanus, and hepatitis). This low vaccination coverage in Penta could be linked to the weakness of advanced catch-up strategies for children.

In our study, analysis showed that all the children (100%) developed a coughing fit associated with fever (97%) and vomiting (53%). These signs and symptoms manifested by these children are the same as those described in the literature in the case of whooping cough [2].

Furthermore, during the first epidemic, information was

not transmitted to the health authorities until one month after the first case had appeared in the sub-prefecture of Linsan Saran. Finally, the appropriate treatment was not instituted until January 2023, three (3) months after the start of the epidemic.

For the first epidemic, which occurred in the sub-prefectures of Linsan Saran and Dougountounn, health workers were not aware of the signs and symptoms, as the disease had been absent for more than three decades. The information also came up very late in the chain of command. The alert was issued on 31 December 2022 and a preliminary investigation was not opened until 1 January 2023. An in-depth investigation was then conducted between 3 and 6 January 2023. During this investigation, samples were taken and sent to Conakry for analysis and confirmation. Despite numerous attempts to establish a biological diagnosis and given that the country had neither the inputs nor the reagents, let alone the human resources trained to carry out this type of analysis, the samples were sent to France on 26 January 2023 and analyzed by the Institute Pasteur in Paris. Biological diagnosis and confirmation of the disease were made on 2 February 2023. All these difficulties demonstrate the weaknesses of the Guinean healthcare system in providing a rapid response to epidemics.

Concerning the second epidemic in Lola, the alert was given on 18 March 2023, followed by a preliminary investigation on 19 March 2023. Samples taken on 23 March were sent to Conakry on 27 March. The laboratory of the National Institute de Public Health de Guinea based in Nongo, which had in the meantime acquired the technical and human resources, carried out confirmatory analyses on 29 March 2023.

Table 8 shows that the response to the pertussis epidemic in the health districts of Lelouma and Mali was marked by delays. For example, the deadlines for taking samples (on 6 January 2023) and for sending samples to the reference laboratories in France (on 26 January) were 20 days apart. The same applies to the shipment of samples, which took place on 26 January. Results were not delivered until 2 February 2023, a period of 7 days. This means that 34 days elapsed between the date of the disease alert and its confirmation by the laboratory. The main reasons for the delays were (i) inadequate logistics for transporting samples from the sampling sites to the reference laboratories; (ii) a lack of human resources trained in the detection of certain vaccine-preventable diseases; (iii) insufficient financial resources for appropriate responses, in particular the cost of internet connection credits for reporting information; (iv) the lack of reference laboratories capable of analyzing samples locally; (v) the lack of inputs and reagents for rapid and reliable biological diagnosis; (vi) the poor accessibility of the affected localities; and (vii) the lack of appropriate information and communication technologies.

In the case of the second epidemic, the time between the alert date and the date on which the sample analysis results were returned was 14 days, three times less than for the first epidemic.

We noted a short period between the taking of samples and the delivery of results (the samples were taken on 27 March and the results delivered on 29 March 2023, a period of just 3 days). The delay was 2 days, 6 times less than during the first epidemic.

The difference in response time between the two epidemics could be explained by the fact that the lessons learned from the first epidemic were applied to the second, demonstrating the responsiveness of staff thanks to the practical application of the training provided, the availability of medicines by the health authorities, the remuneration of health workers and the travel resources granted.

Regarding the use of funds mobilized, the response during the second epidemic shows that 71.15% of the budget was used for field missions by two WHO teams, one from Conakry and the other from the WHO sub-office in Nzerekore. The total cost of these two missions was GNF 82,570,923, i.e. 50.35% (mission from Conakry) and 27.83% (Nzerekore sub-office). In addition to these two missions, supervisory missions by the Nzerekore regional health inspectorate consumed 21.41% of the budget used for the response.

As for the response to the first epidemic, only 11.24% was used for supervisory missions by the regional inspectorate, the prefectural health departments of Lelouma and Mali, and the mission by the WHO sub-office in the Labe region.

In total, the total costs used to respond to the two pertussis epidemics amounted to GNF 261,256,448, or 62.78% for the second epidemic, even though only 50 suspected cases were notified.

Regarding the match between the number of cases notified and the expenditure incurred, we were also surprised to note that although the number of cases was almost twice as high in the sub-prefectures of Linsan Saran and Dougountounny, only 97,255,000 GNF (37.62%) of the budget invested was used. However, during the first epidemic, the WHO field mission, the IRS and the two DPSs used only 11.24% of the amount spent. For the first epidemic, 88.66% of the financial resources were used to carry out active research, purchase medicines, vaccinate people, transport samples, hold coordination meetings, investigate alerts, send inputs, pay for call credits and internet connections, and monitor contacts. In contrast, during the second epidemic, only 28.85% of the total amount was used for the same activities. On the other hand, the 71.15% of the budget used was only for supervisory visits by the IRS, the DPS in Nzerekore and the awareness-raising missions carried out by the WHO teams in Conakry and its sub-office in Nzerekore.

We noted that the amounts used do not consider the number of cases notified, as the health districts that notified more cases used fewer resources. These two situations could be described as efficiency for Lelouma and Mali and effectiveness for Lola. However, the amount used alone cannot explain this difference.

Limitations of the study:

Diagnosis was more clinical than biological due to a lack of reagents and consumables in the country, this could lead to an underestimation or overestimation of the number of cases.

We also did not identify any cases in adults. The dates of onset of cases prior to our survey may be imprecise, which could alter the shape of the epidemic curve. In addition, there is the lack of trained staff to diagnose the disease biologically, the long wait before information is passed on to higher levels for decision-making, the time taken to collect and transport samples, analyses the samples, communicate the results, the duration of the epidemic, and so on. As the confirmatory laboratory was located all the way in France, treatment was only initiated based on suspicion,

We also noted the lack of financial and logistical resources to carry out ring vaccinations to avoid the spread of the disease to surrounding localities hence the cause of the occurrence of the pertussis epidemic in the sub-prefecture of Dougountounny due to the uncontrolled movement of already sick children between the two border sub-prefectures.

6. Conclusion

Patient records were analyzed in the various health facilities concerned. These consisted of searching for suspected cases and interviewing health and community workers to identify the 1st or index case. Active searches for suspected cases were carried outdoor-to-door in communities within a 500-metre radius of each confirmed case.

Checks of children's health records and interviews with parents about their vaccination status were used to assess Pentavalent 3 vaccination coverage.

The activation of the EOC SP in the various health facilities has made it possible to organize regular meetings to share information with a view to consensual decision-making, to set up an effective alert system facilitating the collection and escalation of information between the primary care facilities and the secondary and tertiary care facilities, to carry out an active search for other cases and their contacts, and to provide appropriate responses in the various communities.

More than 80% of the financial resources used for the response have been used for population awareness-raising by the WHO team in Conakry and supervision activities by the health authorities.

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